



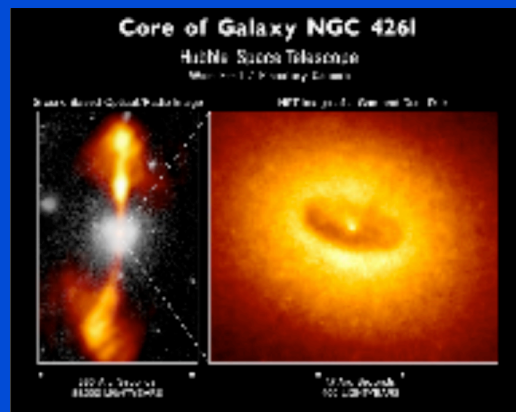
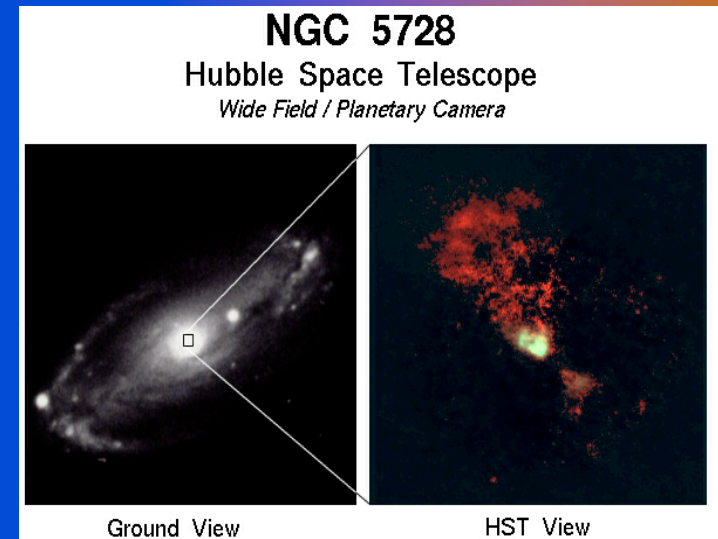
Outflows and relativistic jets in AGNs

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The two AGN classes

- Radio-quiet (Seyferts, QSO)
 - Relatively weak radio emission (but $>$ normal galaxy)
 - No collimated jet (but bipolar flows, ionization cones)
 - No gamma-ray emission $>$ MeV (Dermer & Gehrels '95)

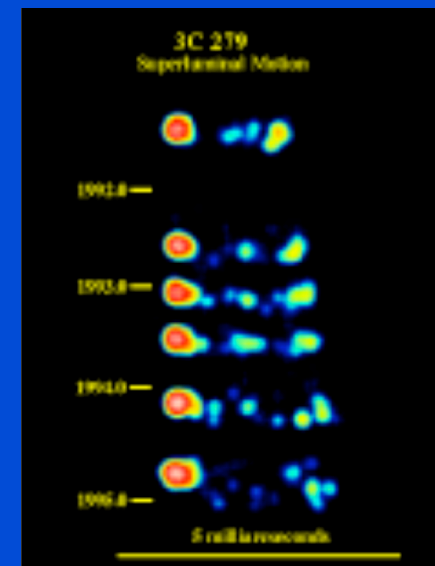
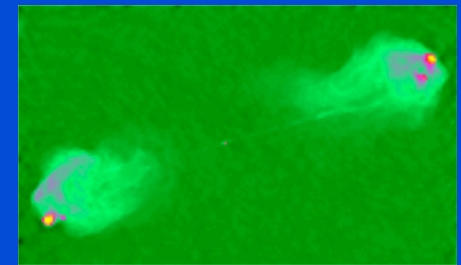
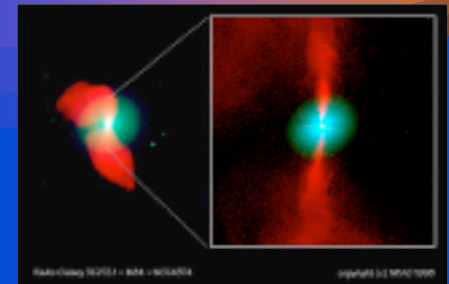


- Radio-loud (Radio galaxies, quasars)
 - Intense radio Emission (synchrotron)
 - Powerful jets
 - Gamma-ray emission $>$ MeV, up to tens of TeV...

Jets in radio-loud AGNs

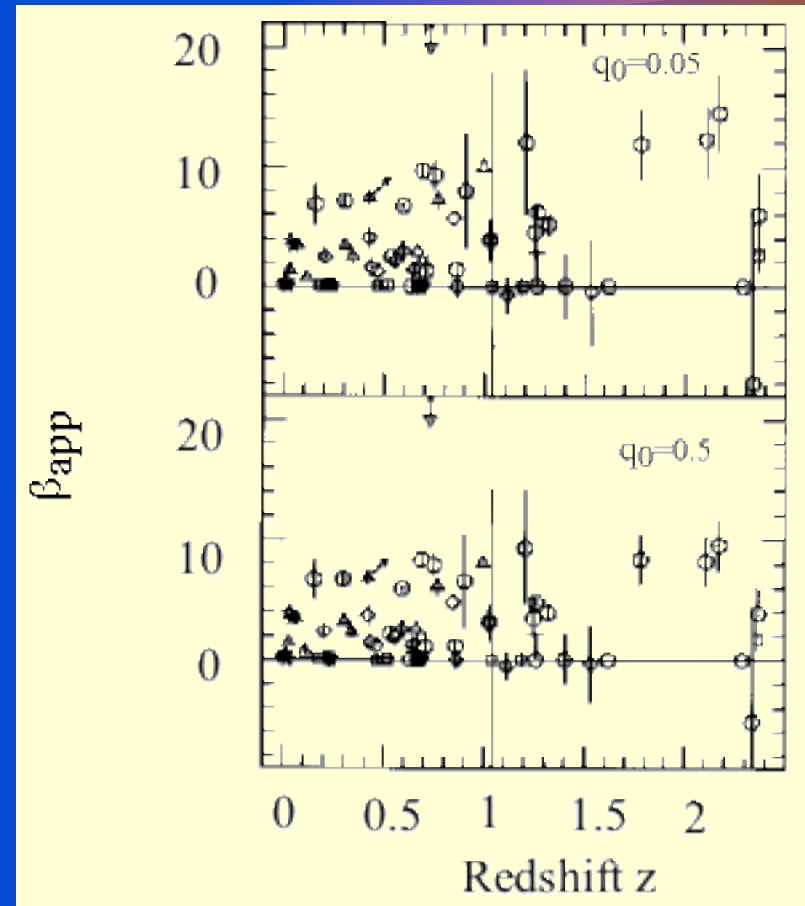
- Large scale ($> \text{kpc}$) one or two sided
 - FR I weak jets, not well collimated
 - Beamed counterparts : BL Lacs ?
 - FR II powerful jets, well collimated, (hot spots)
 - Beamed counterparts : FSRQ ?
- Superluminal motion observed at pc scale (VLBI/VLBA), always one-sided

Apparent V between 5 and 10 c
No clear difference between BL Lacs
and FSRQ !

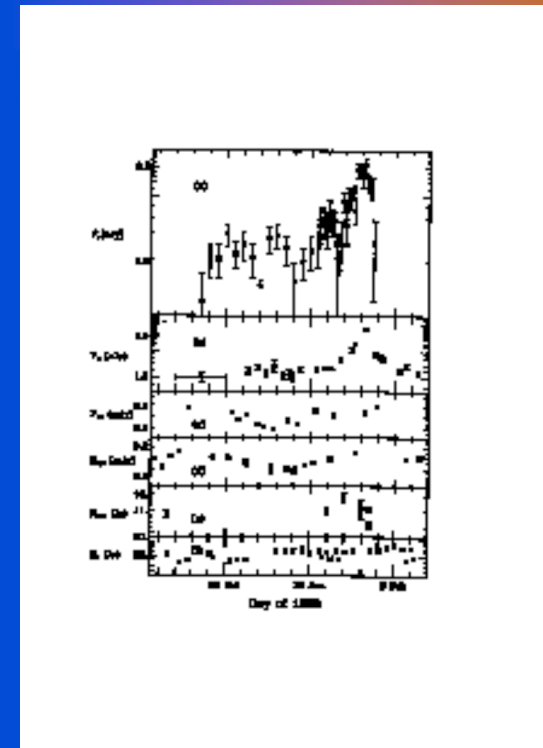
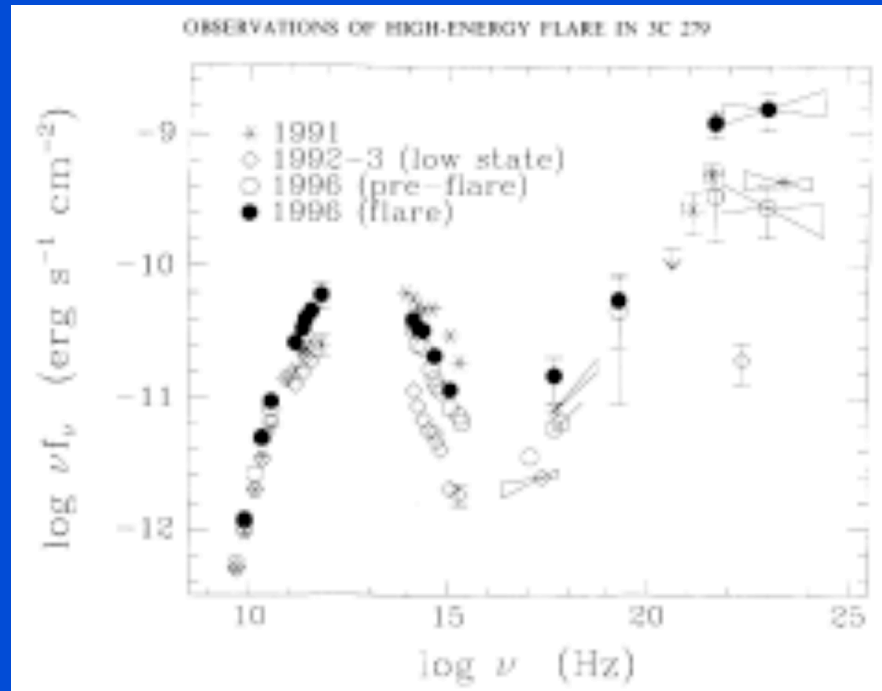


Superluminal motions

- Statistics on known sources (Vermeulen & Cohen '85)
- Compatible with a constant $\beta \sim 10$
- Some larger values discovered?
- Responsible also for Doppler boosting, enhanced variability...



Gamma-ray emitting blazars (grazars)

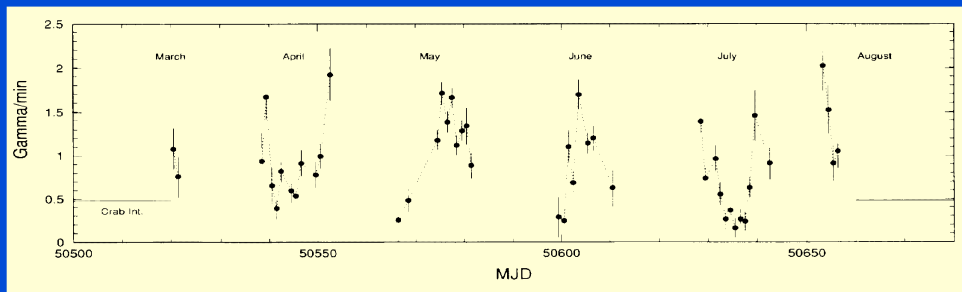


Gamma-ray luminosity can dominate the e.m. spectrum (10^{48} erg.s⁻¹)

Strongly variable, often correlated with other wavelengths, but not in a simple way

Extreme blazars (>100 GeV)

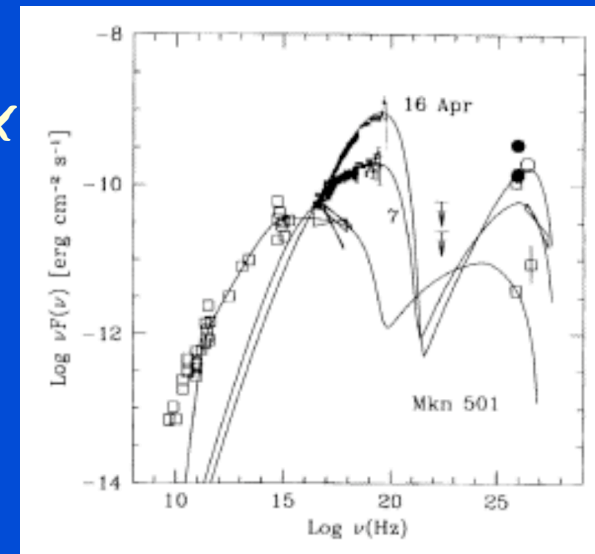
Still more variable (<30%)



Extreme spectrum :

- synchrotron peak in X rays dans les X
- Compton peak at TeV

Correlated variability



«Standard» model for gamma-ray emission

Gamma-ray opacity constraint : lower value of Bulk Lorentz factor, need for relativistic bulk motion

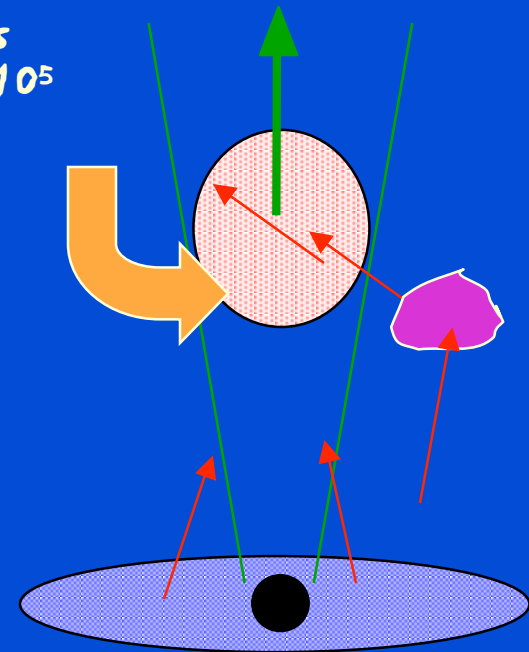
Leptonic processes favoured : Inverse Compton on synchrotron or external photons $e^- (\gamma mc^2) + h\nu \rightarrow e^- (\gamma' mc^2) + h\nu'$

Sources of soft photons

- accretion disk
- optical lines
- synchrotron (SSC)

Relativistic particles injection $\dot{Q} \approx 10^3 - 10^5$
Internal Shocks ?

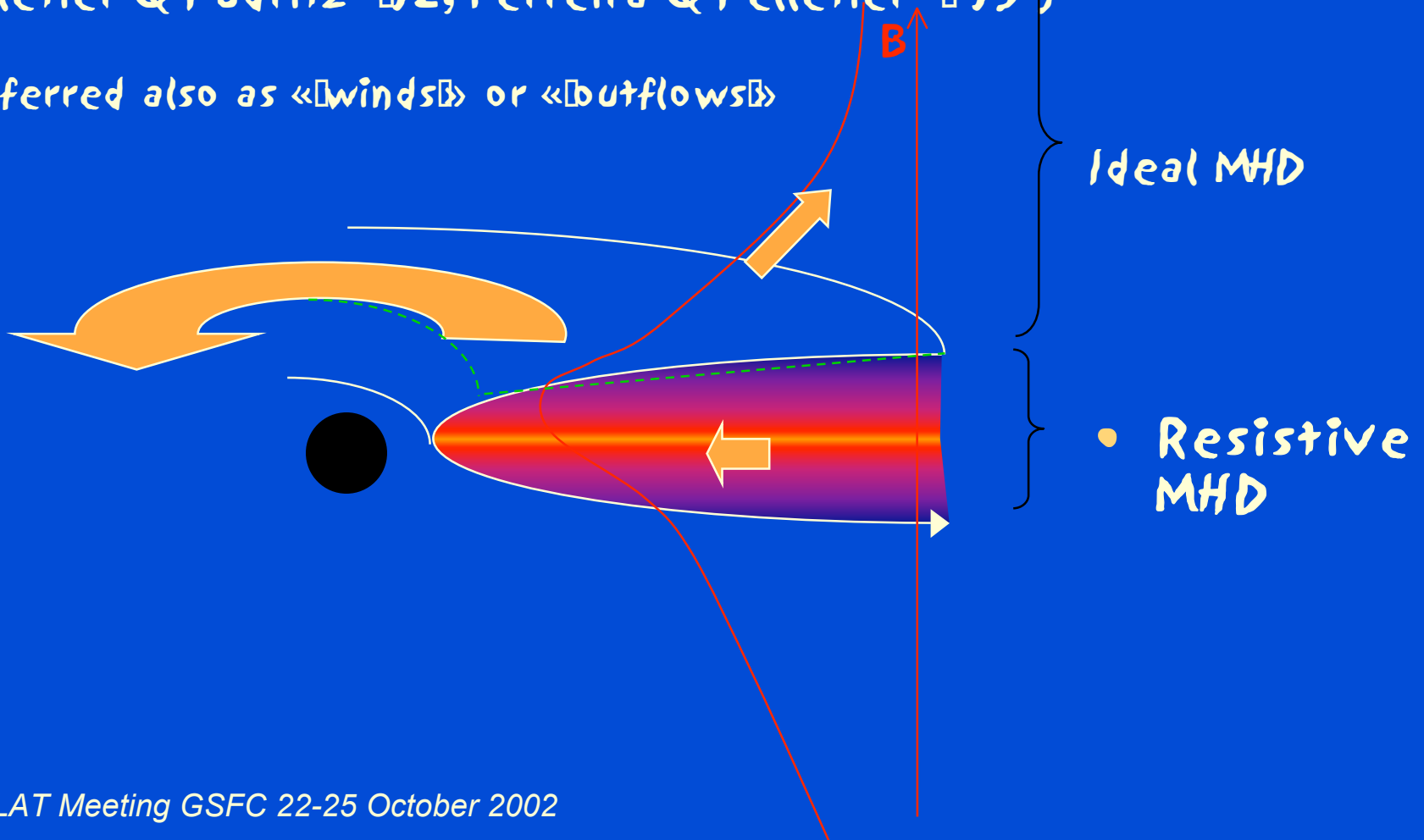
Relativistic jet $\Gamma_b = 10$



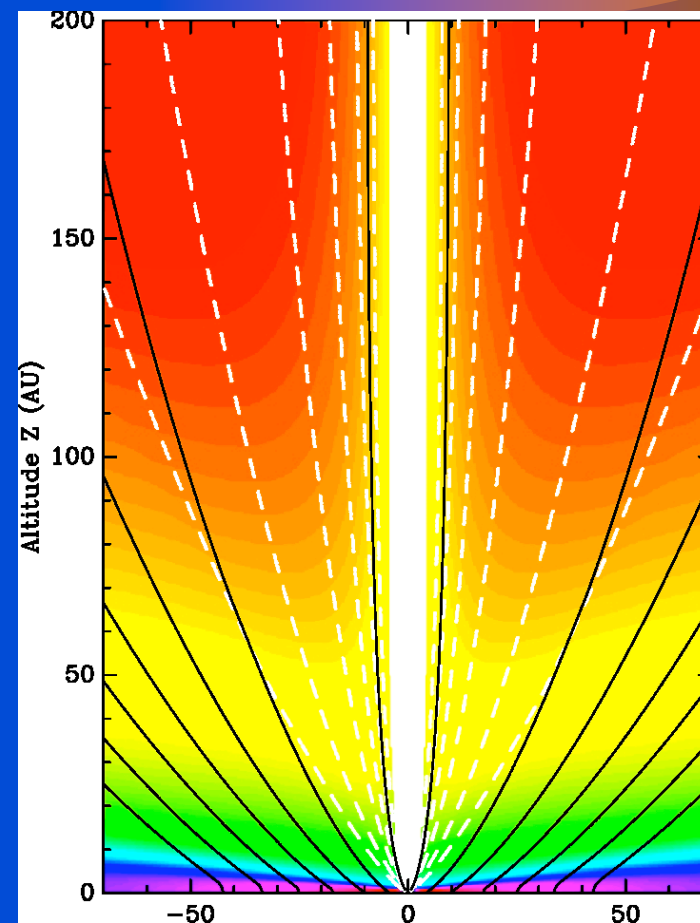
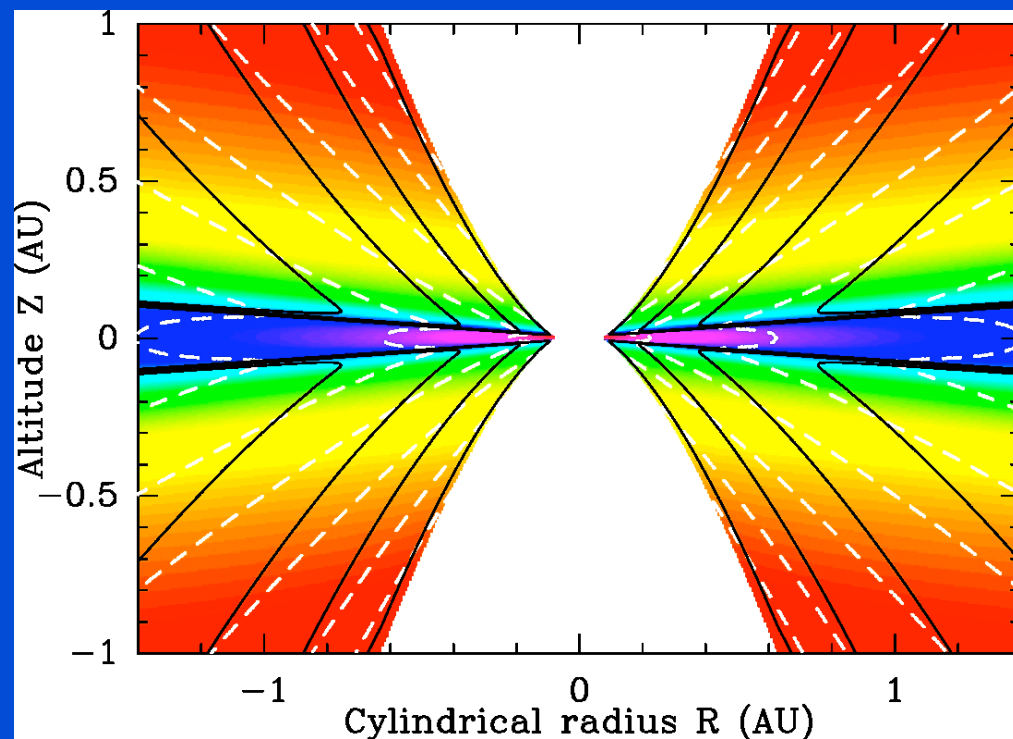
Generation of relativistic jet ?

Powerful jets can be extracted from accretion disks through Magneto-Hydrodynamical process (Blandford & Payne '82, Pelletier & Pudritz '92, Ferreira & Pelletier '93)

Referred also as «winds» or «outflows»



Self-similar Accretion Discs driving Jets (Ferreira, Pelletier...)



- $B \approx$ equipartition
- Ejection efficiency $\dot{M}_{\text{acc}} r^{\frac{1}{2}}$

$$\frac{\dot{M}_{\text{eject}}}{\dot{M}_{\text{acc}}} \approx 0.01$$

Influence of ejection parameter

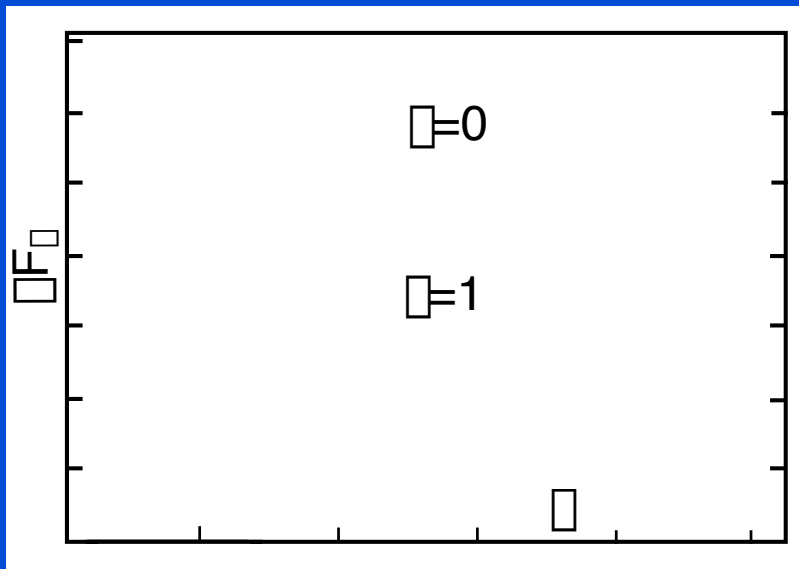
- Disc SED modified by ejection

$$T_{\text{eff}} \propto r^{-q} \quad q = \frac{3\epsilon}{4}$$

- Jet terminal velocity

$$V_{\text{jet}} = \epsilon_0 r_0 \sqrt{2\epsilon\epsilon_0^3}$$

$$\epsilon = 1 + \frac{1}{2\epsilon_0}$$



Low ejection efficiency ϵ
 \rightarrow powerful jets and disks

High ejection efficiency ϵ
 \rightarrow weak jets and disks

«Two flows» model

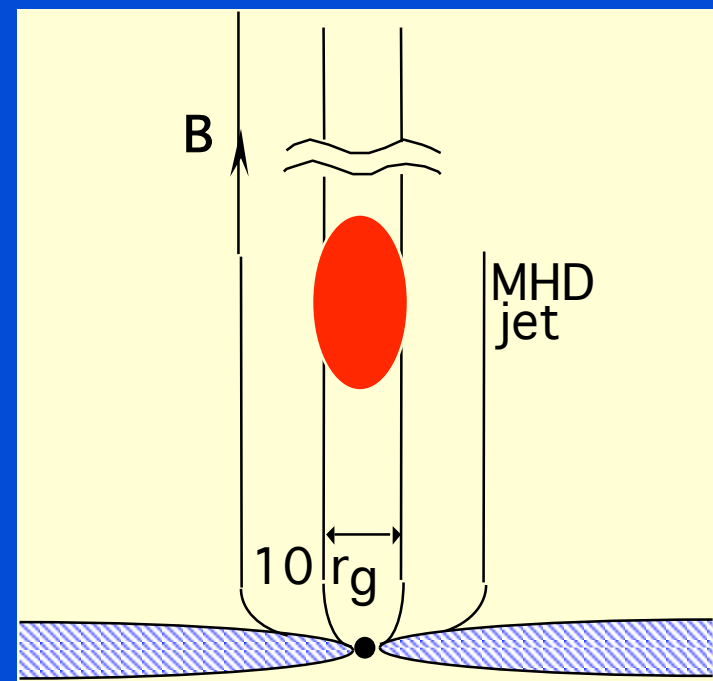
But Relativistic jets difficult to produce and collimate
with equipartition $V_{\text{jet}} \approx V_{\text{Kepler}}$
No high β solution !

Two flows model : 2 distinct flows (Sol, Pelletier, Asséo 1985)

MHD jet $e^- p^+$ mildly
relativistic

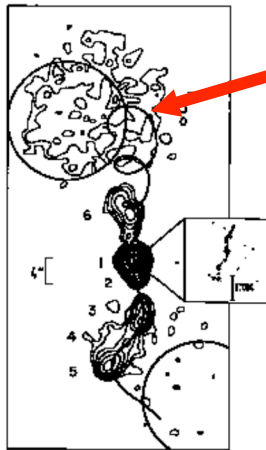
+

Highly relativistic pair plasma



Two-flow model

Account for some contradictions from small scale to large scale jets.



Example = 1928+134

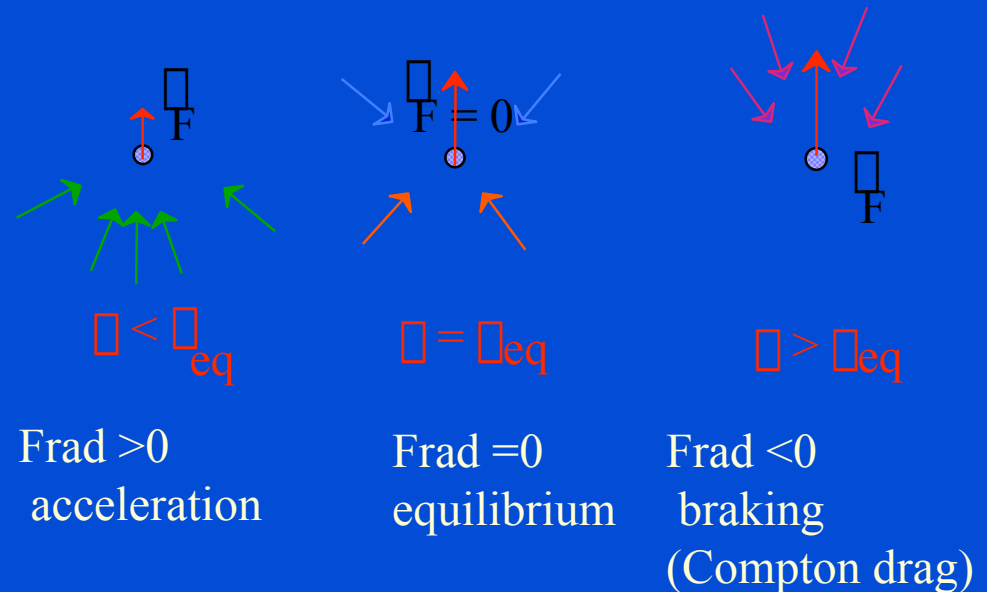
Two-sided jet @ kpc scale

One sided jet @ pc scale
superluminal motion, $v_{app} = 6c$

Either θ is varying by $\sim 50^\circ$
Or θ is varying from 7 to 1.08...

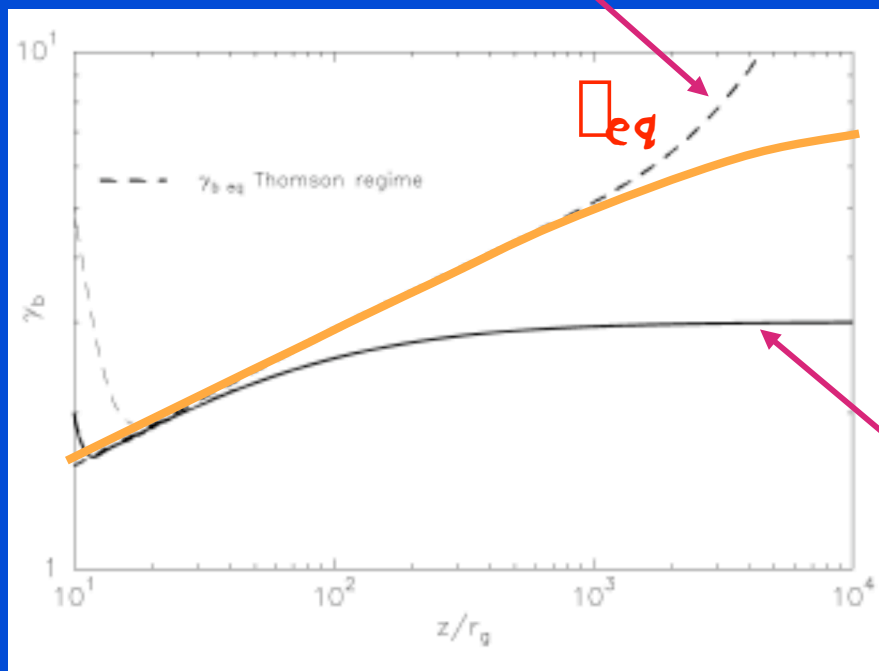
Bulk acceleration of pair plasma

- Compton effect transfers energy and impulsion
- In an anisotropic photon field, directed force (\sim radiation pressure)
- Vanishes in some frame due to relativistic aberration.



O'Deill's Compton Rocket effect

- In the vicinity of an accretion disk, β_{eq} increases with the distance $\propto (z/R_g)^{1/4}$



Hot plasma : same V_{eq} but the force is X by $\langle \gamma \rangle$
(Compton Rocket effect)
Saturation velocity is reached later and is larger

Cold pair plasma : β_b increases but reaches a plateau when $T_{acc} > T_{dyn}$

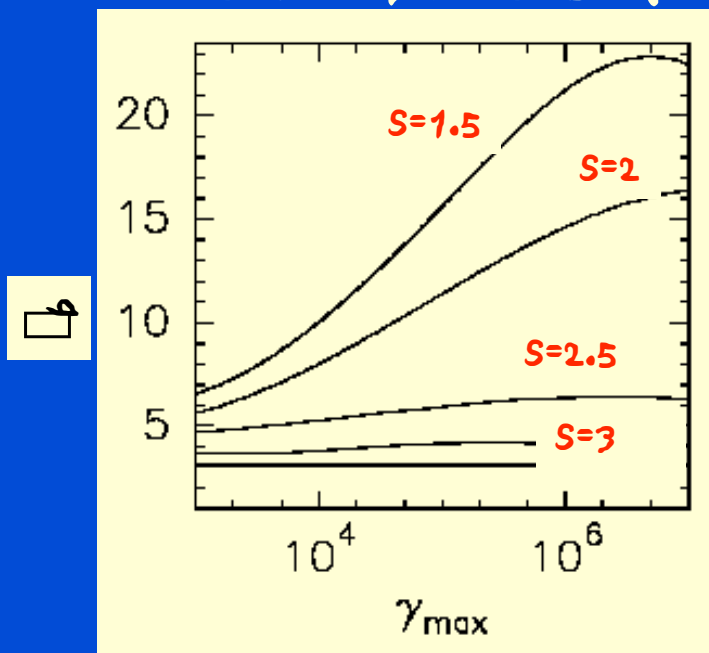
$$\beta_b \propto l_s^{1/7} \propto 2-3 \quad \text{where } l_s \propto \frac{\dot{M} L_{soft}}{4 \dot{M} m_e c^3 R}$$

But cooling faster than acceleration (Phinney) !!
Need for continuous reacceleration at large distance

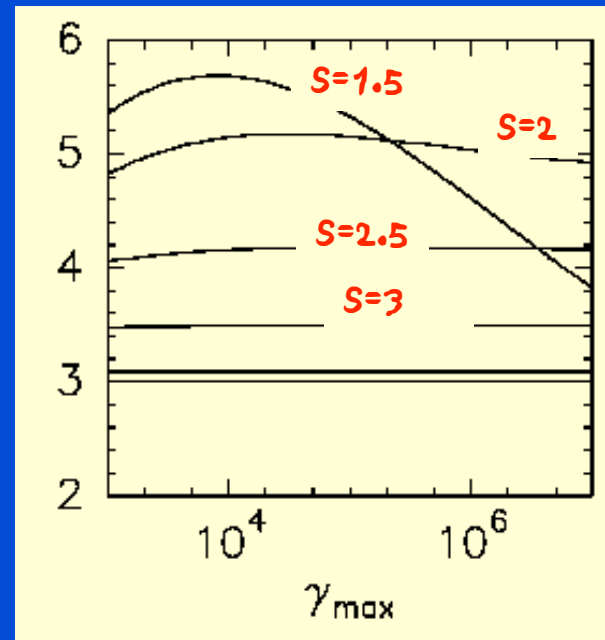
Rocket effect with continuous heating

- standard disk, $L = L_{\text{edd}}$
- power law distribution
 $n(\chi) = n_0 \chi^{-s}$, $1 < \chi < \chi_{\text{max}}$ (Renaud Henri 1998)

$M = 10^8 M_{\odot}$



$M = 10 M_{\odot}$



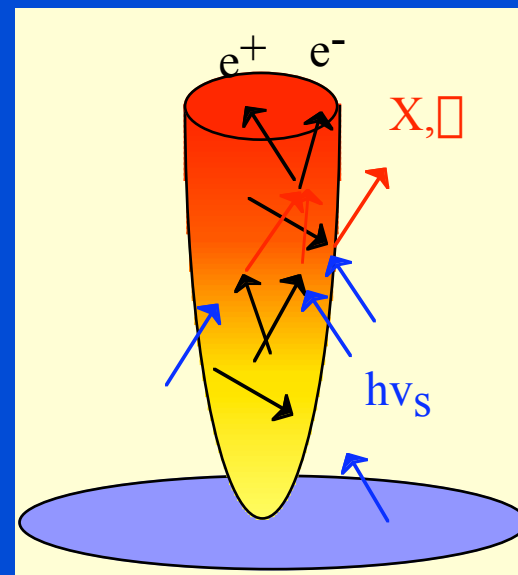
Generation of pair plasma

In situ generation of pair plasma

Feed-back on gamma-ray emission

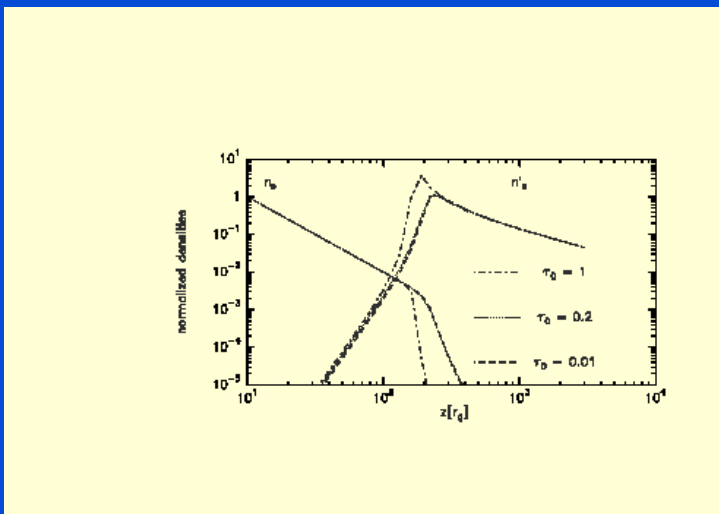
- Some relativistic particles
- X-ray and gamma-ray emission by IC and/or SSC
- $\gamma\gamma$ annihilation forms new pairs
- Continuous reacceleration by MHD turbulence

- Processus must stop ! Add a prescription on maximal random Lorentz factor, balancing an acceleration rate $\dot{\gamma}_b$ with synchrotron and Compton losses

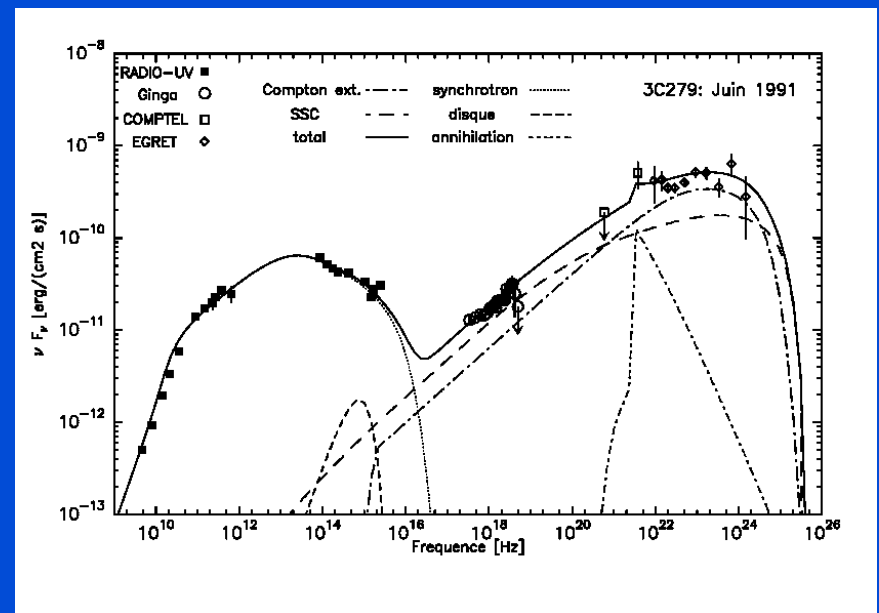


Some results

- Spectral fits



Particle and disk photon density along the jet



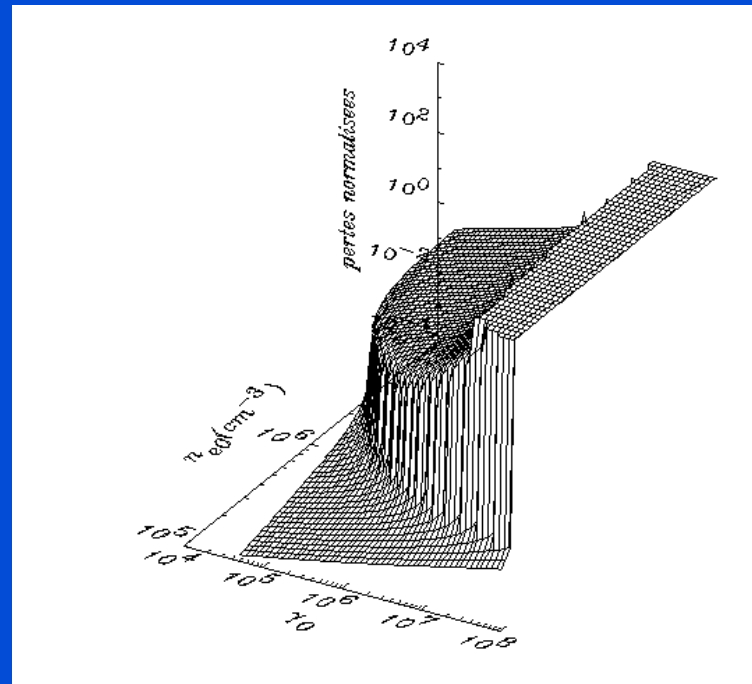
Multiwavelength spectrum

Pair production threshold

- For a given geometry and B field, the solutions depend on initial particle density and the acceleration rate

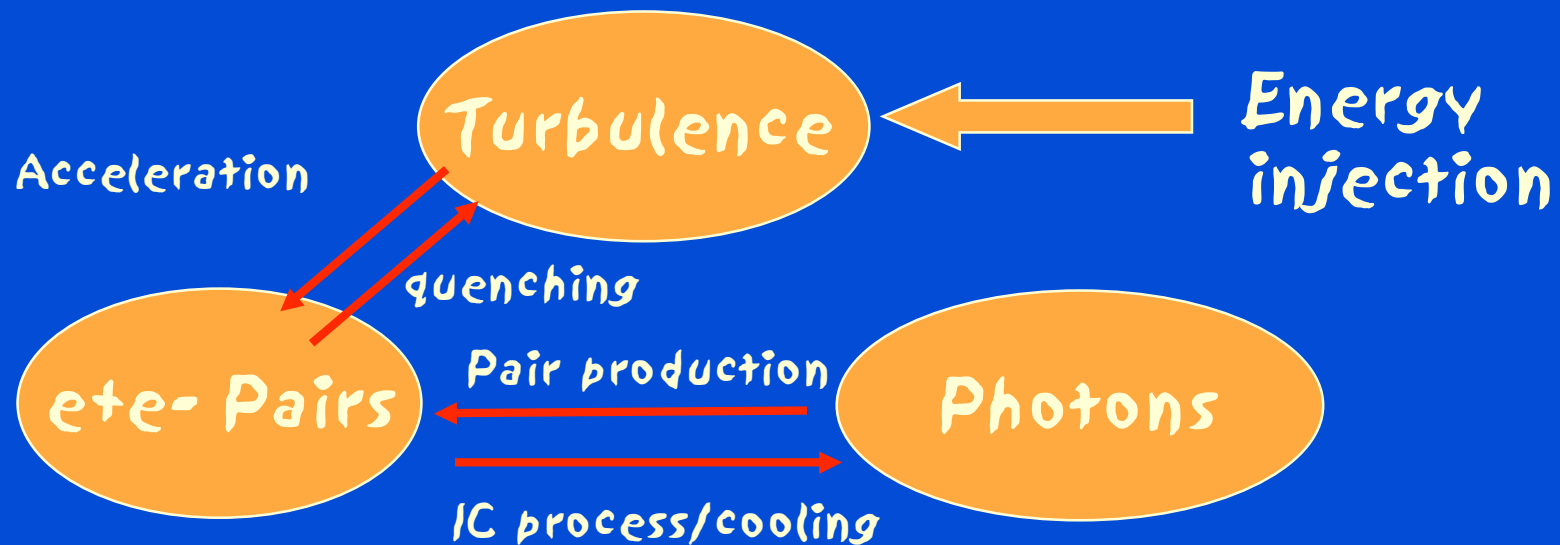
Very sharp transition of jet power when pair production starts : highly non linear

Steady-state solutions probably unphysical, variability expected



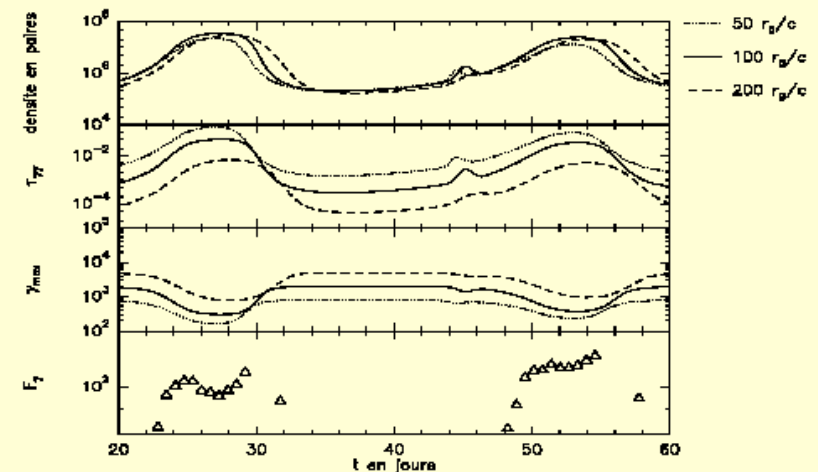
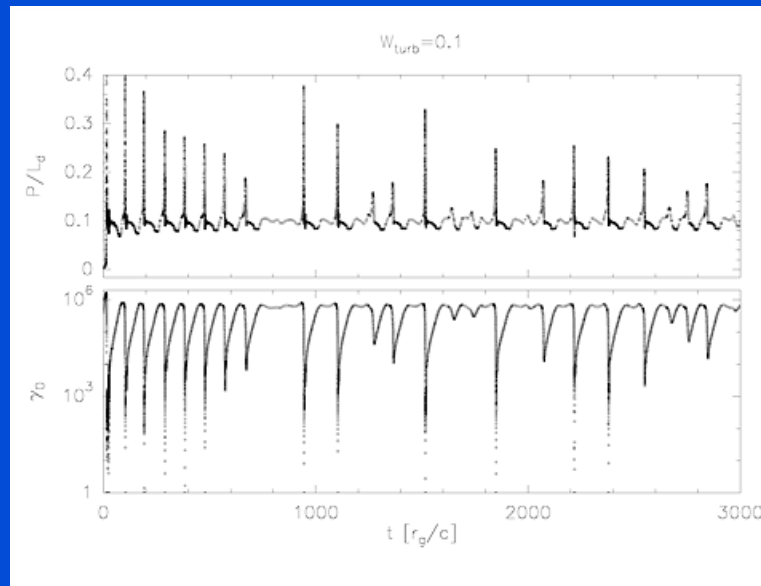
A time-dependant model

- Assume a time-dependant acceleration rate
- Parametrized by $\varpi_b(t)$
- assume $\frac{d}{dt}\varpi_b = Q_{inj} \varpi P_{jet}$



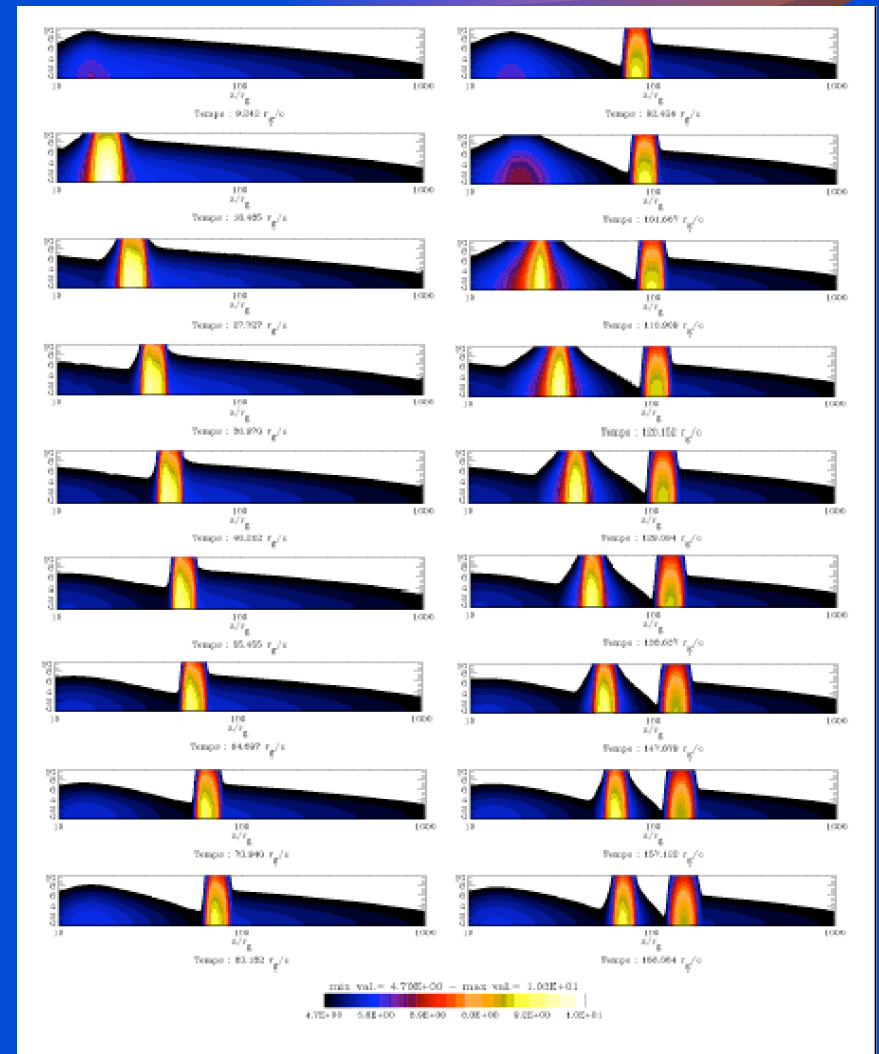
Spontaneously variable solutions

For some values of Q_{inj} (corresponding to the «wall») time-dependent solutions exhibit spontaneous flaring behavior



At least qualitative agreement with observations

Flares associated with the ejection of discrete components



The particle distribution function

Spectra usually fitted with power laws
 $N(\epsilon) \propto \epsilon^{-s}$
 but sometimes in very narrow ranges

Extreme blazars can be fitted equally well with pile-up (quasi-maxwellian) distributions

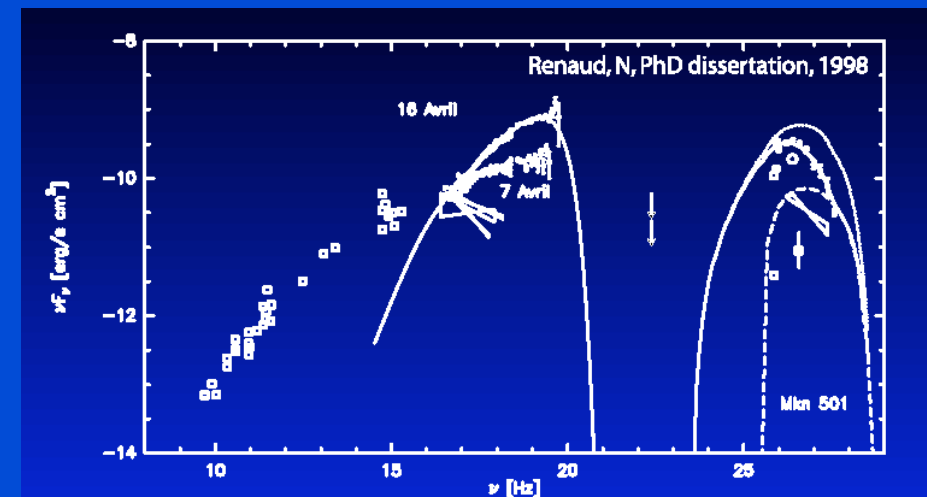
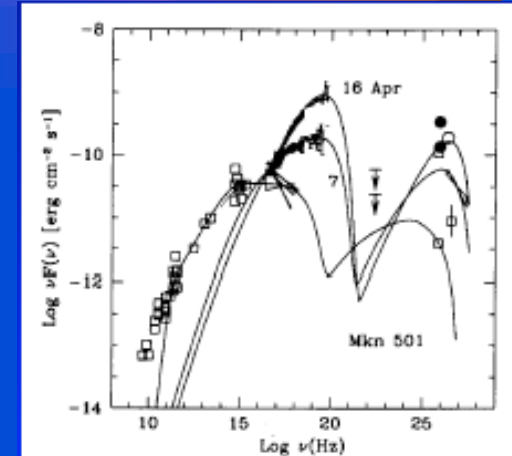
$$N(\epsilon) \propto \epsilon \exp(-\epsilon/\epsilon_{\max})$$

More naturally predicted by bulk turbulence acceleration

Pian et al '98
 $S=1$

$$\epsilon_{\min} = 4 \cdot 10^5$$

$$\epsilon_{\max} = 3 \cdot 10^6$$

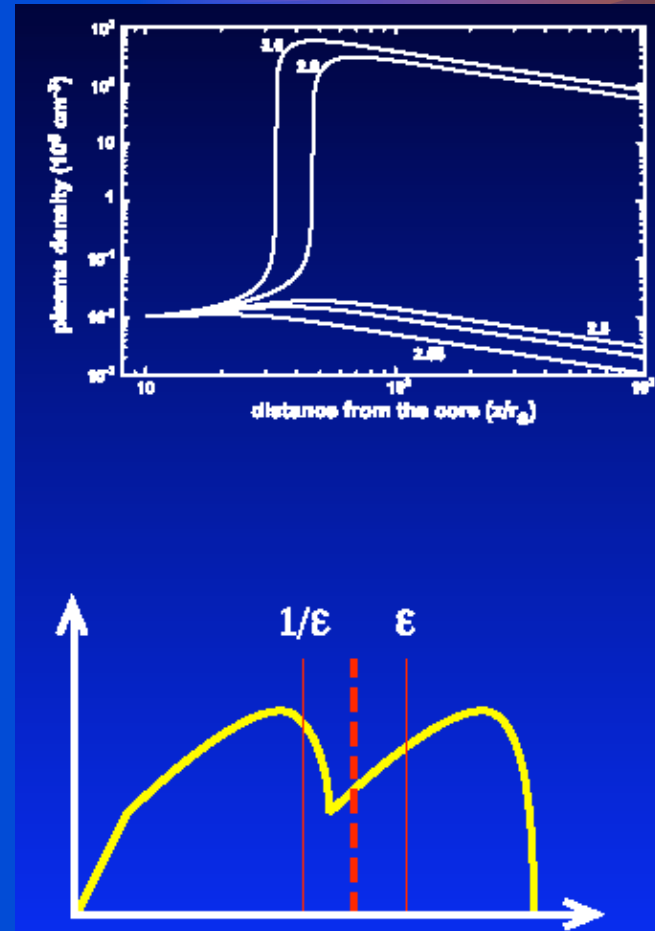


First results with pile-up distribution

Extremely sharp pair transition

Pair creation directly on synchrotron X-ray photons

Violent variability expected



Some conclusions



Pair model can reproduce the qualitative features and the quantitative SED of AGNs

Need for simultaneous multi wavelength and time-resolved spectra to better test the models : leptonic/hadronic, homogeneous/inhomogeneous, pairs or not, particle distribution function...

High sensitivity and energy coverage of GLAST extremely valuable for temporal and spectral resolution, encourage multi- λ campaigns